MERCURY IN THE LAKE SIMCOE AQUATIC ENVIRONMENT

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Ministry of the Environment

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MERCURY

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LAKE SIMCOE AQUATIC ENVIRONMENT

Water Resources Planning Unit
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Water Resources Branch

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1. BACKGROUND TO THE STUDY

Since 1970 when mercury was first measured in fish and sediment from watercourses adjacent to industrial mercury sources (e.g. the St. Clair River - Lake St. Clair system of the the Great Lakes and the English - Wabigoon River system of northwestern Ontario), the Province of Ontario has expanded its surveillance program to lakes and streams throughout Ontario.

Popular angling species have been collected for mercury analysis from Lake Simcoe over the past few years. For the most part, fish from this lake are low in mercury (less than 0.5 parts per million) and suitable for consumption. Some of the larger predatory fish however, most notably walleye (yellow pickerel), do contain levels of mercury that make these fish suitable only for occasional consumption. The very large walleye (over 30 inches in length) are not recommended for consumption at all.

No significant industrial source of mercury in the Lake Simcoe Basin has been identified, therefore, the cause of elevated levels in the large walleye could not be immediately identified. In order to better evaluate the mercury levels and possible sources in the basin, an extensive field survey program was implemented in the winter of 1977. Samples of fish, water and sediments were collected throughout the lake. Existing or past sources that could potentially contribute mercury (municipal discharges, agricultural drainage, sanitary landfill site runoff, etc.) were studied.

The following report outlines the findings of the investigation and draws conclusions about the significance of mercury in fish from Lake Simcoe.

2. MERCURY IN THE LAKE SIMCOE ENVIRONMENT

2.1 Bedrock

The Geological Branch of the Ministry of Natural Resources performed a reconnaissance sampling of bedrock outcroppings in the Lake Simcoe vicinity. In all, sixteen locations were sampled and the results from all stations showed low mercury levels in the rock (10 parts per billion or less). On the basis of this survey, it can be assumed that exposed bedrock is not a significant source of mercury in the Lake Simcoe basin. Sampling locations and results are presented in Appendix 1.

2.2 Lake and River Sediments

Most documented studies on mercury conclude that mercury is associated mainly with fine-grain sediment material (organics and clay size). A sediment sampling program was initiated during the winter of 1977 to determine the spatial distribution of mercury in the sediments of Lake Simcoe and its tributary streams.

Sediment samples were obtained through 'coring', a procedure that allows the different strata or layers of sediment to remain intact. The different layers of the core can be subsampled to determine the geochemical history of past trace element inputs even at levels which would have been below detection in water samples.

A. Lake Sediments

The east side of Lake Simcoe is relatively shallow (less than 10 meters deep) with a patchy sand veneer over stiff glacial till. Fine-grained sediment materials brought into this area by tributary streams and through shoreline erosion are resuspended by wave action until they settle in deeper, quiescent waters towards the center of the lake. Kempenfelt Bay contains the deepest waters of Lake Simcoe (over 40 meters) and provides a depositional environment

characterized by very soft silts and clays. Cook Bay is protected from severe wave action and soft organic silts accumulate in this area as well. The lakebed composition of Lake Simcoe is illustrated in Figure 2.1.

Analysis of the sediment core samples presented in Figure 2.2 (detailed information is provided in Appendix 2) shows that sediments on the east side of the lake, the south end of Lake Couchiching and in some stream mouths, are clean sands and tills with geochemistry typical of background levels for the area (mercury levels are in the 0.01 to 0.03 parts per million range). In the deeper, central portion of the lake dominated by soft silts, there is a slight enrichment of mercury (0.06 ppm) in the surface sediments. Subsamples from deeper sections of the same cores (below 28 cm), although comparable in grain-size and organic content to the upper layer, were at background (0.01 to 0.02 ppm) concentrations. Surface sediments from the deeper stations in Cook Bay contain somewhat higher mercury levels (0.07 to 0.09 ppm) than central lake sediments, but again the sediment in the lower sections of the cores contain background levels of mercury.

In Kempenfelt Bay, the surface sediment mercury concentration is highest near the City of Barrie (up to 0.98 ppm) but decreases with distance away from Barrie. At the mouth of the bay, mercury in surface sediments is 0.11 to 0.12 ppm, an order of magnitude higher than background levels. As in the other areas, mercury concentrations deeper in the cores from western Kempenfelt Bay declined but not as quickly as at mid-lake stations. This effect can probably be attributed to a higher sedimentation rate in the western part of the bay.

The increasing mercury concentrations in surface sediments from the mouth of Kempenfelt Bay towards Barrie, in spite of comparable grain-size and organic content found at other deep lake stations, indicates a source or more likely, a combination of minor sources from the urbanized area. Studies conducted by Environment Canada

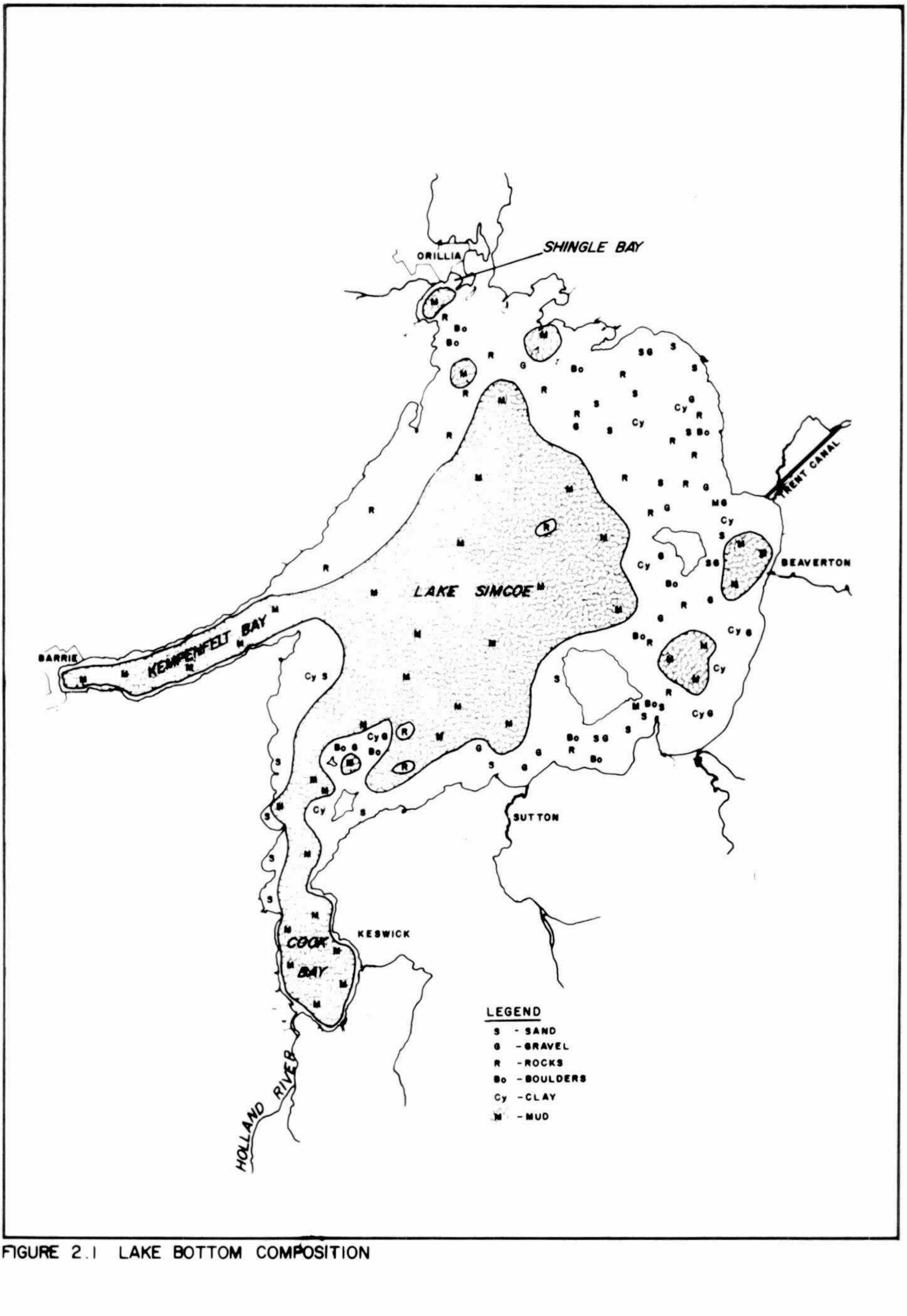

FIGURE 2.1 LAKE BOTTOM COMPOSITION

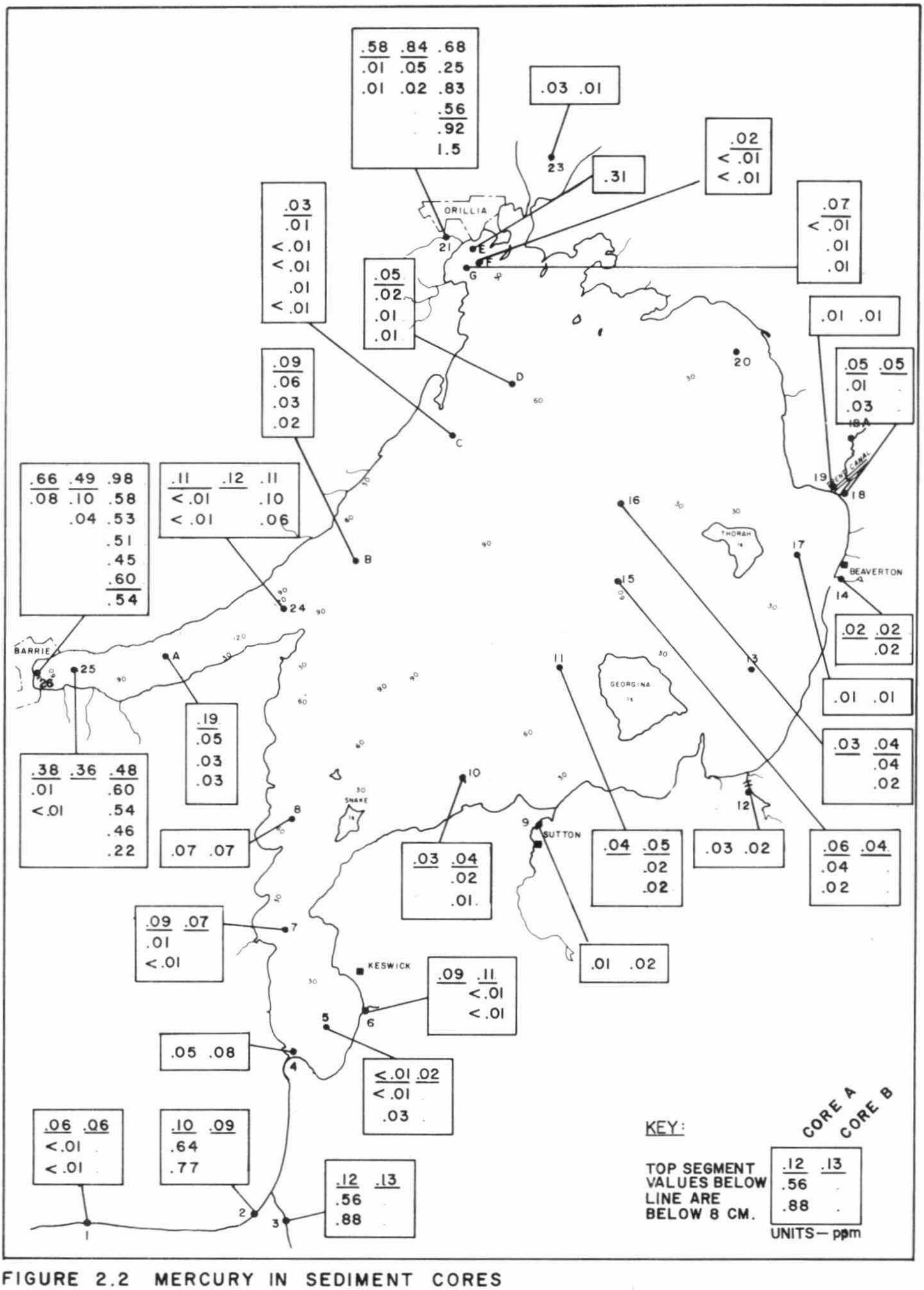

FIGURE 2.2 MERCURY IN SEDIMENT CORES

(Kemp et al)* report that sedimentation rates in the Great Lakes range from 0.7 to 13.4 mm/yr. Assuming that the sedimentation rate in western Kempenfelt Bay is somewhere in the middle of this range, it is apparent that mercury levels began increasing several decades ago and the rate of increase may be accelerating.

A core from Ben's Ditch downstream from the Orillia STP outfall reveals elevated mercury levels persisting well down in the core (1.5 ppm at 32 cm). Since this creek is subject to scour and redeposition, it does not represent a consistent depositional environment that would allow one to draw conclusions about variation in upstream discharges with time. Shingle Bay at Orillia has a patchy accumulation of sand and silt over bedrock. Where fine grained materials could be found, the mercury content was elevated (0.31 ppm). Evidence again points to the urban wastewater discharges as source of mercury in this area of the lake.

A visual representation of surface sediment mercury levels is presented in Figure 2.3. The decline from high values in the western end of Kempenfelt Bay to the mouth of the Bay and then the open lake is quite evident. The difference in mercury levels between the sand/till zones and the mud bottom is also quite clear.

The cores collected from Lake Simcoe during February and March, 1977 were analysed for lead, zinc, arsenic, copper and chrome as well as mercury. The relative distributions of various heavy metals in sediments can aid in establishing the origin of these substances. In the Great Lakes, Kemp and Thomas** reported that man-induced enrichment of elements over natural levels is greatest for mercury followed in roughly descending order by lead, zinc, cadmium and copper. It is the authors' opinion that, generally, the same trends occur in Lake Simcoe.

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*Kemp A.L.W., Anderson, T.W, , Thomas, R.L., and Mudrochova, A. 1974. "Sediment rates and recent sediment history of Lake Ontario, Erie and Huron". Journal of Sed. Petrol., Vol.44, No.1, pp.207-218.

**Kemp, A.L.W. and Thomas, R.L., "Impact of Man's Activities on the Chemical Composition in the Sediments of Lakes Ontario, Erie and Huron", Water, Air and Soil Pollution, 5 (1976).

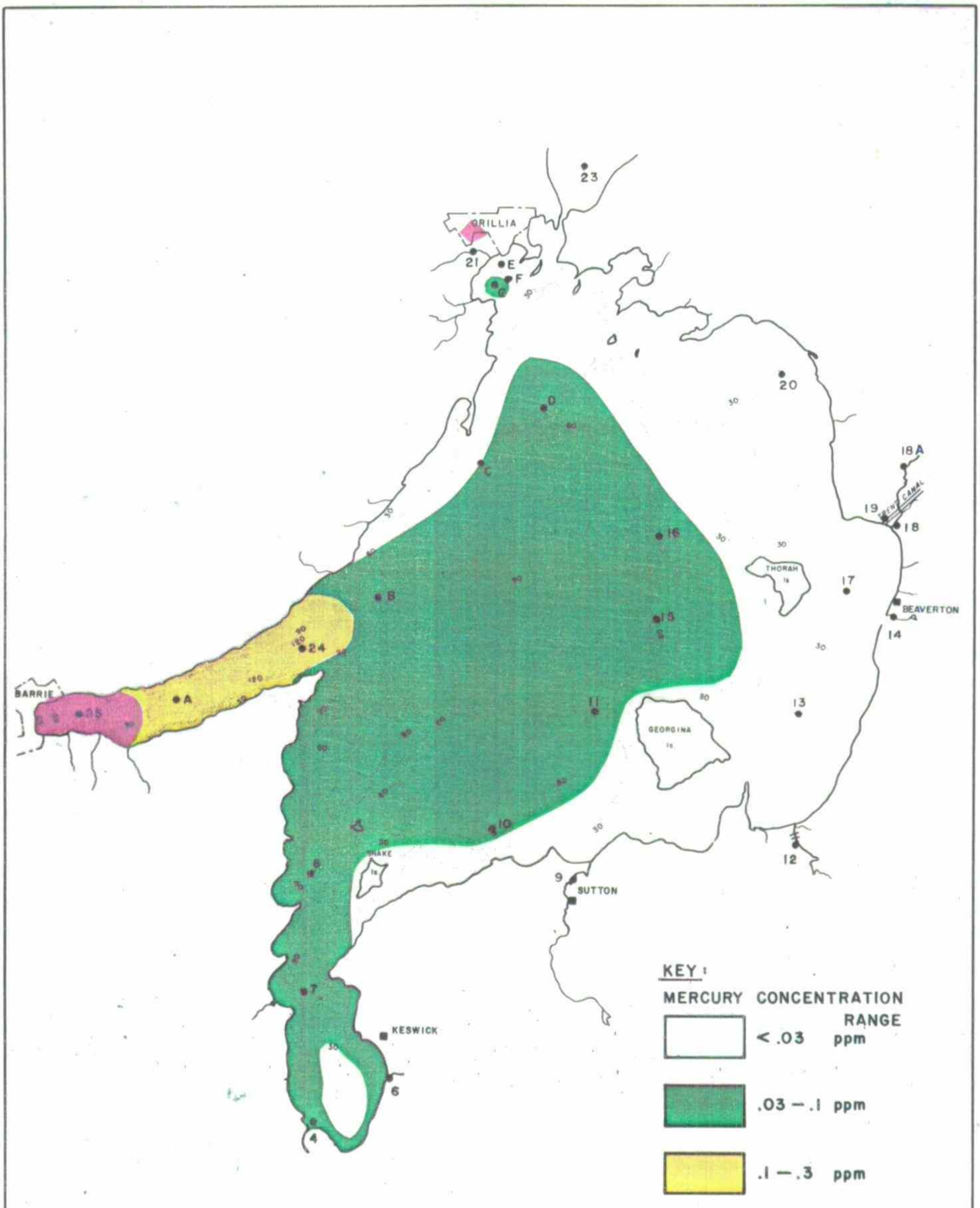

FIGURE 2.3 SPATIAL DISTRIBUTION OF MERCURY IN THE SURFACE SEDIMENTS OF LAKE SIMCOE

The surface distribution of lead, zinc, copper and chrome follow the same pattern as mercury with the most elevated levels found near the major urban centres. The degree of enrichment of chrome was greater than the other elements, particularly in Kempenfelt Bay. Arsenic levels, while quite low throughout the lake, showed moderate enrichment in sediments collected from the Holland River and Cook Bay. This is consistent with agricultural usage of products containing arsenic.

Detailed sediment core information for inland watercourses in Ontario is extremely limited; therefore, a comparison of Lake Simcoe data with another lake with similar features, development, etc. cannot be made. However, to provide some reference points, Lake Simcoe mercury levels are compared with levels found in lakes Huron, Erie and Ontario in Table 2.1.

From this table it can be seen that mercury in open lake sediments of Lake Simcoe (Station 11) are roughly comparable to largely undeveloped Lake Huron with surface enrichment values 2 to 3 times higher than historical levels. The highest mercury levels in Lake Simcoe occur in the Western end of Kempenfelt Bay (Station 26) and these levels are comparable to levels in Lake Erie.

It must be recognized that while the surface mercury concentrations and enrichment factors are numerically comparable, the impact of mercury contamination is not comparable as indicated by the relatively small area of Lake Simcoe affected in relation to the widespread occurrence of these levels in the lower Great Lakes.

B. Tributary Streams

Sediment samples were collected near the mouths of the major tributary streams. Results of analysis are presented in Figure 2.2.

Generally, mercury levels in sediments were low (0.01 to 0.02 ppm) and indicative of background concentrations. Samples from the Jersey

TABLE 2.1 A COMPARISON OF MERCURY LEVELS IN LAKES SIMCOE, HURON, ERIE AND ONTARIO

STATION LOCATION	CORE SEGMENT (cm)	Hg VALUE (ppm)	SURFACE ENRICHMENT* FACTOR
Lake Simcoe (Stn.11) - central lake west of Georgina Island	0-7 31-39	0.05 0.02	2
Lake Simcoe (Stn.26) - west end of Kempenfelt Bay near Barrie	0-1 20-30	0.98 0.04	25
Lake Huron** - Mid Lake west of Goderich	0-2 20-30	0.20 0.07	3
Lake Erie** - middle of Western Basin directly south of the Detroit River.	0-1 40-50	1.45 0.05	29
Lake Erie ** - Middle of Central Basin south of	0-1 30-40	0.99 0.09	11
Lake Ontario** - Mid-Lake between Toronto and the Niagara River	0-1 15-20	3.47 0.08	43
Lake Ontario** - Mid-Lake south of Cobourg	0-1 25-30	2.65 0.03	88

* Surface enrichment factor - surface value - by depth value

** Kemp, A.L.W. and Thomas, R.L., "Impact of Man's Activities on the Chemical Composition in the Sediments of Lakes Ontario, Erie and Huron," Air and Soil Pollution, 5(1976).

and Holland rivers, however, were elevated, in the range of 0.1 ppm in the surface layers. Deeper layers of cores from the Holland River samples exhibited even higher levels (0.6 to 0.9 ppm) of mercury. In light of these higher levels, additional sampling was carried out throughout the Holland River basin. The results are shown in Figure 2.4.

On the Schomberg (West Branch of the Holland River), background levels (0.01 to 0.02 ppm) were measured in the drainage canals around the muck farming area of the Holland Marsh and in the marsh soils as well. Background to slightly elevated levels (0.01 to 0.06 ppm) were measured in the river reach downstream of the agricultural area.

Background mercury levels were measured in Aurora Creek upstream from Aurora and in the East Holland River upstream from Newmarket. Concentrations up to 0.38 ppm were measured in cores immediately downstream from Newmarket. Elevated concentrations (up to 0.88 ppm) were also measured in the deeper sections of cores collected in both the east and west branches of the Holland River near the confluence. This area of the river is normally very slow-moving and would permit sediment deposition. However, motor-boat propeller wash, spring high flows and storms could resuspend and redistribute sediments throughout this area. The high mercury levels in sediments in the lower Holland River likely results from urban discharges to the East Holland River. There is no evidence in the analysis of the sediment cores to suggest that agricultural activities in the Holland Marsh are contributing significant loadings of mercury to Lake Simcoe.

2.3 Mercury in Water

Water samples were collected at each sediment sampling station and analysed for mercury. Concentrations at all lake stations were below detection limits (0.02 to 0.03 ppb). May 1977 mercury levels in tributaries discharging to the lake varied from below detection

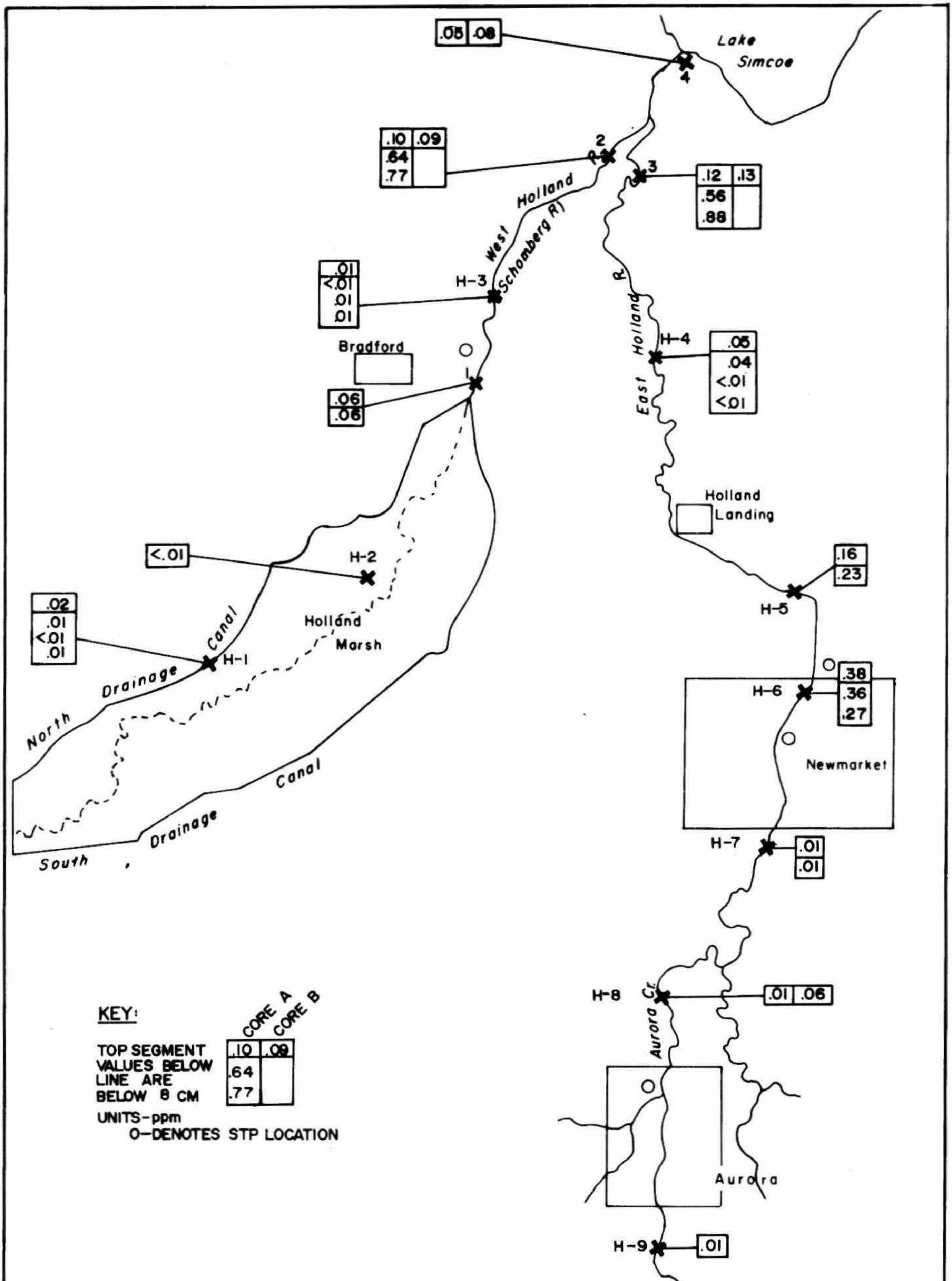

FIGURE 2.4 MERCURY IN SEDIMENTS FROM THE HOLLAND RIVER BASIN.

limits up to 2.2 ppb near the mouth of the Holland River. Results are shown in Figure 2.5.

Because of the elevated mercury levels measured at the Holland River mouth in May, 1977, an intensive sampling of the Holland River basin was carried out in June, 1977. With the exception of one water sample collected in the north drainage canal of the Holland Marsh (0.09 ppb), mercury concentrations in water from the east and west branches of the Holland Marsh were at or below detection levels. Results are shown in Figure 2.6.

Mercury found in water is usually associated with suspended solids. The measurable concentrations of mercury found in the May, 1977 survey of tributary streams is probably accounted for by the fact that the higher streamflows of the spring were carrying resuspended particulates downstream and the mercury associated with these particulates was analysed with the water samples.

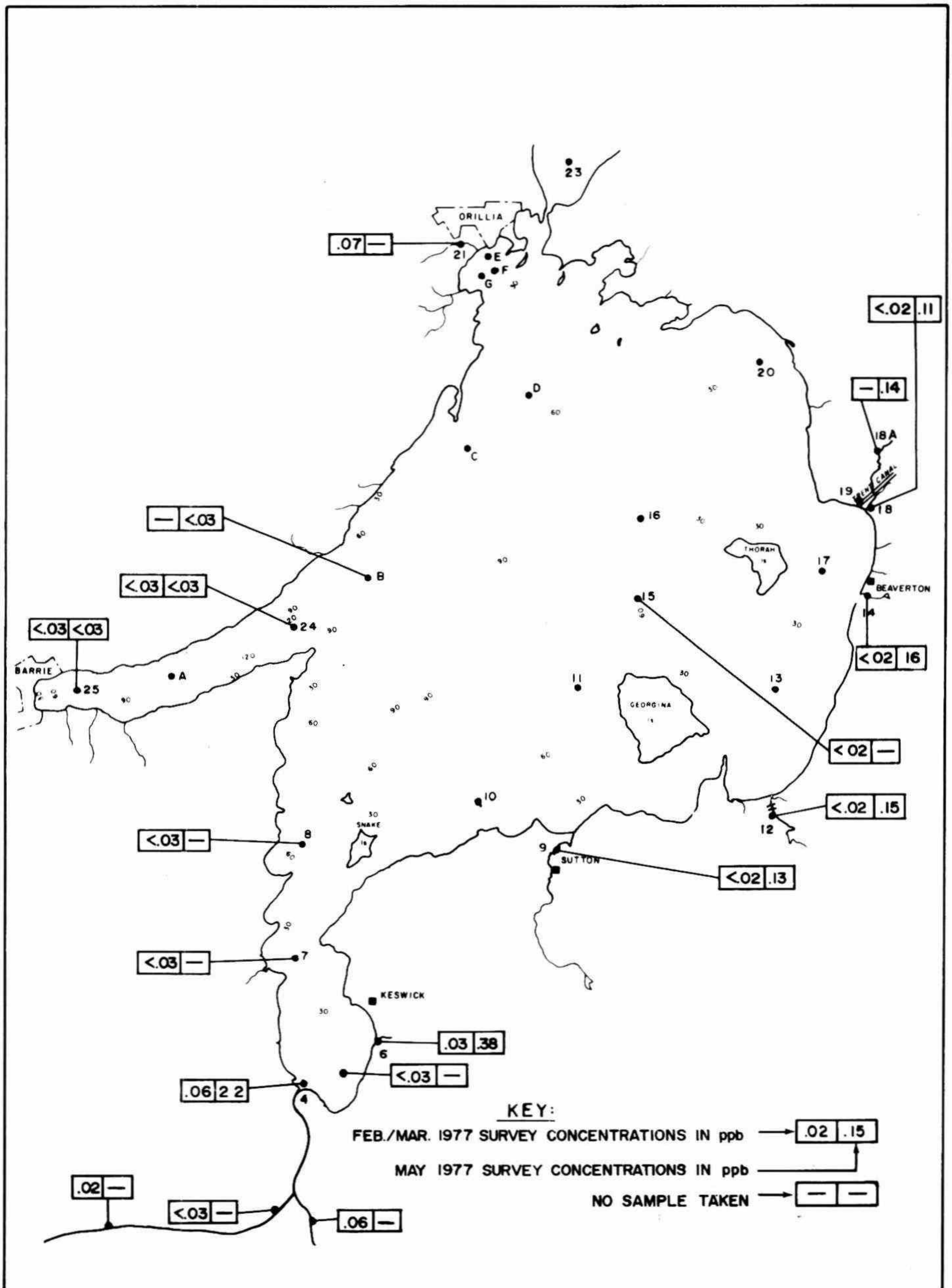

FIGURE 2.5 MERCURY IN LAKE SIMCOE WATER. (Parts per billion).

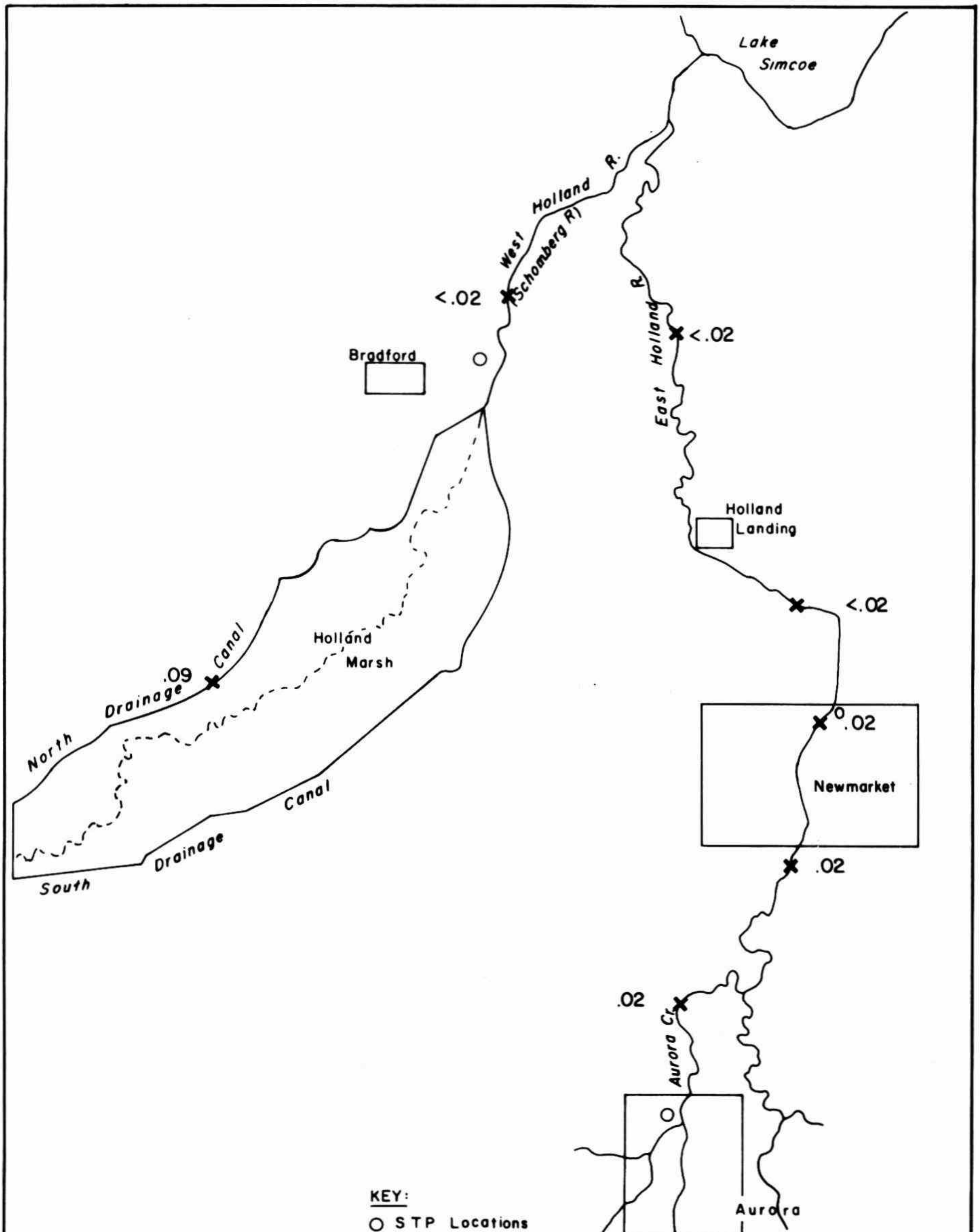

FIGURE 2.6 MERCURY IN HOLLAND RIVER BASIN WATER. (Parts per billion).

3. SOURCES OF MERCURY

Mercury is an element with a wide variety of industrial, commercial and domestic uses. It could enter the aquatic environment from a number of sources associated with man's activities.

Large industrial users of mercury such as chlor-alkali plants or pulp and paper mills have never existed in the Lake Simcoe Basin and, as mentioned earlier, natural geological sources do not appear to be contributing mercury to the system.

As part of the study of mercury in the Lake Simcoe aquatic environment, sources such as municipal sewage treatment plant effluents, sanitary landfill sites and sewage sludge disposal areas were evaluated and other potential sources such as the atmosphere and golf courses are discussed.

3.1 Mercury from Sewage Treatment Plants

Sampling was undertaken to determine the extent of mercury inputs to Lake Simcoe from sewage treatment plant effluents. Apart from industrial sources, there are several household products containing mercury (some of the common products are listed in Table 3.1) which may eventually end up in domestic sewage.

The final treated wastes from a sewage treatment plant include a liquid fraction (effluent) containing some suspended solids and a semi-solid fraction referred to as sludge. The liquid effluent is discharged directly to a watercourse, whereas the sludge is usually placed in landfill sites, burned or applied to agricultural lands.

A. Effluent

Table 3.2 shows mercury loadings from sewage treatment plants to Lake Simcoe. The figures do not reflect such other possible major sources as by-passed raw sewage or urban stormwater which do not

TABLE 3.1

COMMERCIAL PRODUCTS CONTAINING MERCURY

PRODUCT	COMPOUND	PRODUCT DIVISION
bleach, freckle creams & ointments	ammoniated mercury	cosmetics
	mercuric chloride	cosmetics
	mercuric oxide	cosmetics
freckle lotions	ammoniated mercury	cosmetics
conditioning (skin) cream	ammoniated mercury	cosmetics
face wax	mercurized wax	cosmetics
skin freshener	ammoniated mercury	cosmetics
misc. disinfectants	mercury compounds	disinfectants
lawn pesticides	mercurous chloride	pesticides
	organic mercury compounds	pesticides
roach killer	mercuric chloride	pesticides
skin ointment	ammoniated mercury	ointments
	mercury bichloride	ointments
ophthalmic ointment	mercuric oxide	ointments
	ammoniated mercury	ointments
fungicidal ointment	mercury salicylate	ointments
antialgae paints	mercury soap	paints
	mercuric oxide	paints
	phenyl mercury oleate	paints
flat wall paint oil, primers & sealers	mercury	paints
hypotest solution	mercuric chloride	photo products
mercury intensifiers	mercuric chloride	photo products
red pigment	mercuric sulphide	pigments
yellow & brown pigment	mercuric oxide	pigments

(FROM - METALS IN MUNICIPAL WASTEWATER MOE 75-1-43)

TABLE 3.2: MERCURY CONCENTRATIONS AND LOADINGS IN EFFLUENTS FROM STPs IN LAKE SIMCOE BASIN

Plant	Mercury Concentration in Effluent ug/l	Mercury Concentration in Effluent Sampling Date	Estimated Average Conc. ug/l	Plant Hydraulic Loading (MIGD)	Annual Loading of Mercury to Lake Simcoe (grams/year)
Barrie	.05	May 18/76	.04	4.2	279
	.05	**			
	.03	Oct 24/77			
	<.04	Nov 7/77			
Orillia	.03	**	.03	3.0	149
	<.03	Oct 24/77			
	<.04	Nov 7/77			
Newmarket	.02	Dec 21/76	.02	2.7	90
	<.05	Jun 14/77			
	<.03	Aug 3/77			
Aurora	.03	Dec 21/76	.03	2.1	104
	<.03	Jun 20/77			
Bradford	.03	**	.03	0.56	28
Uxbridge	.09	Mar 22/77	.09	0.31	46
Beaverton	*	**	-	0.24	-
Sutton	.22	Mar 9/77	.09	0.18	27
	<.03	Oct 21/77			
	<.03	Oct 23/77			
Holland Landing	.04	Mar 9/77	.04	0.11	7
Cannington	*	**	-	0.10	-

*No Data
**Sampling date not available
MIGD - Million Imperial Gallons per Day

receive treatment. The values in the table are based on limited sampling. In most cases, the figures represent an average of only a few values per year. As such they only give a rough indication of the amount of mercury that may be discharged by the various plants. In order to obtain seasonal trends in mercury output or to better quantify the annual loadings, more frequent sampling over a greater time span would be required.

B. Sludge

Sludge applied to agricultural land is another potential source of mercury to Lake Simcoe. Little is known about the form in which mercury occurs in sludge; however, there is evidence to suggest that methylation of mercury can occur in agricultural soils (Rogers)*.

The volumes of digested sewage sludge and the amount of mercury in the sludge from sewage treatment plants in the Lake Simcoe Basin are listed in Table 3.3.

Noting that much of the sludge from the City of Barrie's STP is spread on fields outside the Lake Simcoe Basin, it is estimated that from 60,000 to 70,000 cubic meters of sludge containing 3,500 to 4,000 grams of mercury are applied to lands draining to Lake Simcoe or its tributary streams.

Because of the high affinity between mercury and solid soil surfaces, mercury persists in the upper layers of soil and is not a significant threat to ground water. The aquatic environmental concern about the land application of sewage sludge relates to that portion of the sludge that washes from the land surface to

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*Rogers, R.D., "Methylation of mercury in agricultural soils." J. of Envir. Quality Vol.5 No.4 1976. pp.454-458.

TABLE 3.3: MERCURY CONCENTRATIONS IN SLUDGE FROM STPs IN LAKE SIMCOE BASIN

Water Pollution Control Plant	Mean Mercury Concentration in Sludge (ug/1)	Volume of Sludge Applied to Field (M^3/yr)	Amount of Mercury Applied to Field (grams/yr)
Barrie	60	54600*	3275*
Orillia	50	16800	840
Aurora	16	17100	275
Newmarket	105	18600	1950
Uxbridge	5.3	4550	25

* Most of the City of Barrie's sewage sludge disposal areas lie outside the Lake Simcoe Basin.

watercourses. Based on studies done in Ontario **, the amount of sludge washing off agricultural lands is usually less than 5 percent of the total amount applied. Using the 5 percent value, it is estimated that sewage sludge disposal in the Lake Simcoe area could contribute up to 200 grams per year of mercury to watercourses in the basin. Most losses would be to tributary streams and the amount of mercury actually reaching the larger rivers and the lake, thus becoming available to the fish, cannot be ascertained. However, the authors feel that the amount would be quite small.

3.2 Sanitary Landfills

Within the Lake Simcoe drainage basin there are six sanitary landfills in Simcoe County, six in York Region and three in Durham Region (see Figure 3.1). One of these sites near Barrie was sampled for mercury during the survey to determine if sanitary landfills could be a possible mercury source. Surface runoff from the City of Barrie's landfill was found to contain 0.64 ppb of mercury in a single grab sample.

Runoff from sanitary landfills varies significantly with precipitation. Quantification of mercury loadings from landfills would require a major survey effort exceeding the budgetary and manpower resources available for completion of this study. While mercury loadings were not defined and their magnitude cannot be compared to other sources, sanitary landfills do appear to release small amounts of mercury that could ultimately reach the lake.

3.3 Atmospheric Sources

Mercury is present in trace quantities in all parts of the environment including the atmosphere. Because of its relatively high vapour pressure, mercury can evaporate from rock and soil or water surfaces and volcanic activity can also introduce mercury to

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**P. DeAngelis, Min. of the Environment, Pers. Comm., August, 1978.

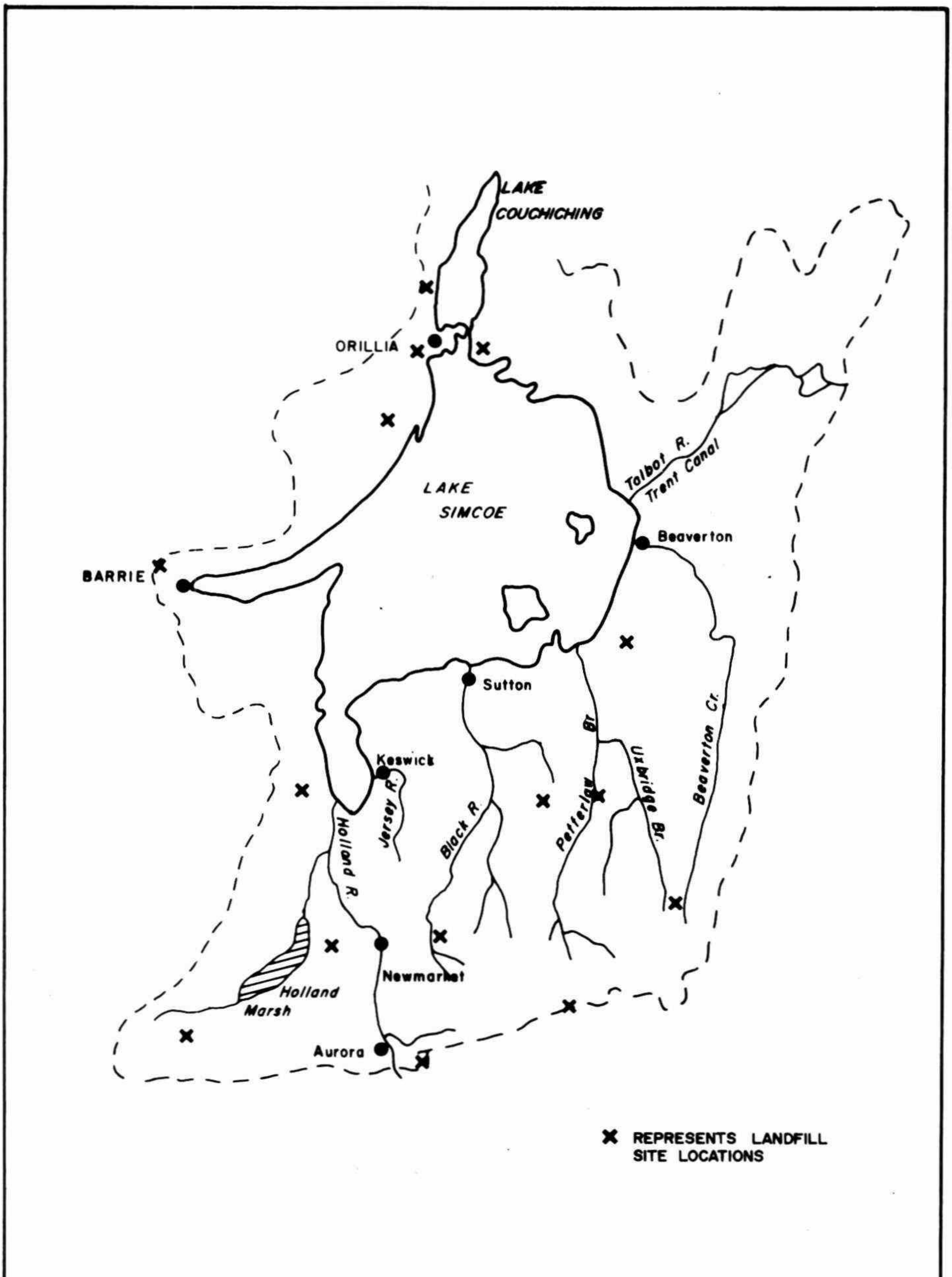


FIGURE 3.1 LOCATION OF SANITARY LANDFILL SITES.

the atmosphere. As well as these natural sources, mercury is liberated in industrial emissions (eg. chlor-alkali plants); smelting of metals, spreading of mercurial compounds for fungus control; the burning of fossil fuels (coal, oil and natural gas) and many other sources.

Mercury in the atmosphere returns to the earth by three processes: precipitation (rain and snowfall); dry fallout of particulate matter; and, absorption of mercury vapour at the earth's surface.

Little is known of the magnitude and significance of atmospheric mercury loadings as they relate to water, sediment and fish. Ontario is currently funding a study with the goal of reliably determining the atmospheric deposition of mercury on water and land. Results of this study will not be available for about two years. It is not possible, therefore, to evaluate the relative significance of atmospheric mercury input to the Lake Simcoe basin in comparison to the other sources.

Snow samples were collected from the Keswick and Holland Marsh areas during the winter of 1978 and analysed for mercury. Concentrations in the snow from both areas were below the detection limit (0.04 ppb).

3.4 Mercury on Golf Courses

Compounds of mercury are used by some golf course greens-keepers to prevent the formation of snow mould on greens. On some courses mercurial compounds are also used on fairways for fungus control.

Most golf courses are built in the vicinity of natural streams or artifical ponds and streams that are designed to enhance the landscape and difficulty of the course. Most watercourses are located close to the greens and, thus, there is the possibility that mercurial compounds used on the grass will find their way to these watercourses (particularly during spring runoff or a heavy rain

shortly after application). Mercury entering these watercourses may be carried downstream and may be taken up by fish.

Studies are underway now to determine the mobility of mercury applied to golf courses in order to evaluate the significance of this source. It is possible that golf courses in the Lake Simcoe basin are contributing to the total mercury loadings. Because of funding and staff limitations, studies of specific golf courses around Lake Simcoe were not carried out as part of this project.

4. MERCURY IN LAKE SIMCOE FISH

4.1 Results of Analysis

Through a co-operative program of the Ontario Ministries of Natural Resources and Environment, fish from Lake Simcoe have been routinely collected and analyzed for mercury since 1970. A summary of the results showing the year of collection; species; number of fish in the sample; mean, minimum and maximum mercury concentration; and, mean, minimum and maximum length of the fish samples are contained in Appendix 3. A size-specific breakdown of mercury levels in popular angling species from Lake Simoce is contained in Table 4.1.

In addition to these data, fish caught during the 1920's, 1950's and 1960's were obtained from the Royal Ontario Museum's collection. Flesh samples were taken from these fish and analysed for mercury. The results of museum fish analysis are also reported in Appendix 3.

4.2 Pathways of Mercury and Bioaccumulation

Mercury, whether naturally occurring or from a man-made source, can be converted by micro-organisms in lake or streambed sediments to the methylmercury organic form.

Methylmercury is absorbed by fish either directly from the water passing over their gills or ingested with the organisms which form their diet. Since fish eliminate mercury at a very slow rate, the concentration in their body may gradually increase even with low levels of methylmercury in the water and sediments. Mercury levels in fish increase with the length of exposure and quantity of mercury contained in the food eaten. Large, old, predatory fish (i.e. fish whose diet consists primarily of other fish) will contain much more mercury than smaller and younger fish, or fish that have a varied diet (i.e. invertebrates, algae, etc.).

TABLE 4.1: MERCURY LEVELS BY SPECIES AND SIZE OF LAKE SIMCOE FISH
(From "Guide to Eating Ontario Sport Fish - 1978")

SPECIES	Fish Size in Centimeters									
	15	15-20	20-25	25-30	30-36	36-46	46-56	56-66	66-76	76
Largemouth Bass	-	A	A	A	A	A	B	-	-	-
Smallmouth Bass	-	A	A	A	A	B	B	-	-	-
Yellow Perch	A	A	A	A	A	-	-	-	-	-
Northern Pike	-	-	-	A	A	A	A	A	A	A
Walleye (Yellow Pickerel)	-	-	-	A	A	A	B	B	C	D
Lake Trout	-	-	-	-	A	A	A	A	A	B
White Sucker	-	-	-	-	A	A	A	-	-	-
Whitefish	-	-	-	A	A	A	A	-	-	-
Rock Bass	-	A	A	A	A	-	-	-	-	-
Ling (Burbot)	-	-	-	-	-	-	-	A	B	B

Key:

Symbol	Mercury Level (ppm)
A	less than 0.5
B	0.5-1.0
C	1.0-1.5
D	1.5
-	Projections not made for this size range

Long-term bioaccumulation is well illustrated in Lake Simcoe walleye (yellow pickerel).

Analysis of the stomach contents of adult Lake Simcoe walleye shows that these fish feed on yellow perch, white sucker, freshwater herring, emerald shiner, sunfish, rock bass and several other species as well as crayfish, frogs and aquatic insects. Young-of-the-year walleye feed primarily on young suckers, perch, minnows, other small fish, crayfish, frogs and insect larvae. (MacCrimmon and Skobe)*. Like almost all living organisms, the fish that walleye prey upon do contain some mercury. This constant, low mercury intake bioaccumulates in walleye with time as illustrated in Figure 4.1. It is quite evident that as the walleye gets larger and older the mercury concentration continues to climb. As walleye approach the 55-60 cm (24 inch) length or about 7+ years of age, mercury levels begin to exceed 0.5 ppm (the unrestricted consumption guideline) and fish larger than about 75 cm (30 inches), 13+ years of age, can exceed 1.5 ppm (the upper limit for occasional consumption).

The following table shows the age at which fish from Lake Simcoe may exceed 0.5 ppm mercury.

TABLE 4.2

Age of Fish When Mercury Level may Exceed 0.5 ppm

Species	Age (years)
Walleye (pickerel)	7 +
Smallmouth bass	7 +
Largemouth bass	12 +
Lake trout	10 +
Ling	9+

*MacCrimmon, H.R. and Skobe, E. "The Fisheries of Lake Simcoe", Ontario Department of Lands and Forests, 1970.

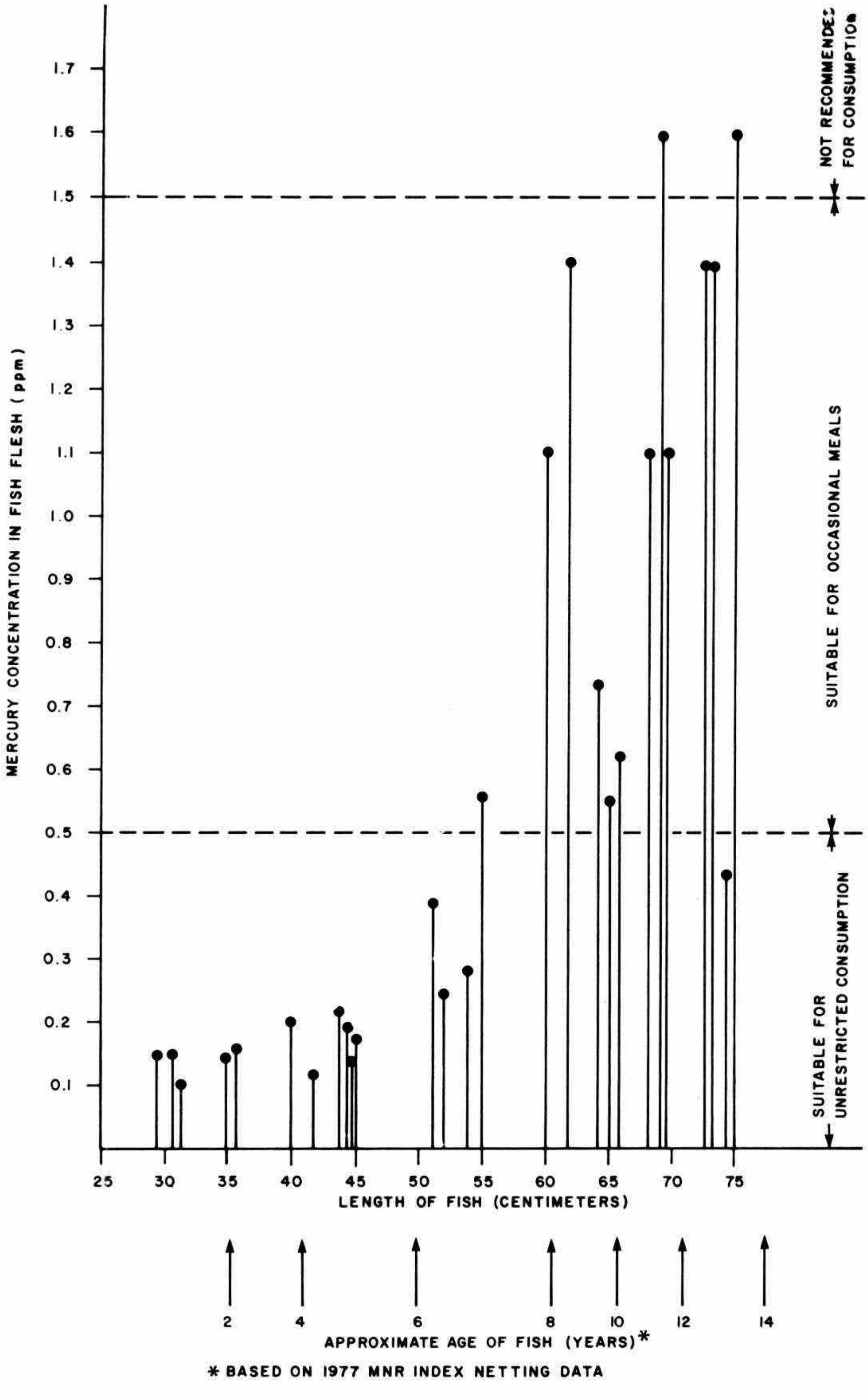


FIGURE 4.1 MERCURY LEVELS IN LAKE SIMCOE WALLEYE COLLECTED DURING 1977

As shown in Table 4.1, mercury concentrations in some other species from Lake Simcoe, namely - largemouth bass, smallmouth bass, lake trout and ling can exceed 0.5 ppm in the larger and older fish. Levels, however, seldom exceed 1.0 ppm. These fish are also predators living, as do pickerel, mainly on other fish and the long-term bioaccumulation as described above is the likely cause of elevated level of mercury in these fish.

Northern pike are also predatory fish but they do not contain elevated mercury levels. This may be a result of their more varied diet which includes snakes, young waterfowl, leeches and aquatic insects as well as other fish (MacCrimmon and Skobe). The lower levels may also relate to the fact that a 30-inch pike may be only 6 years old.

4.3 Historical Trends of Mercury Levels in Lake Simcoe Fish

Samples of whitefish, rock bass, yellow perch, northern pike and cisco were obtained from the Royal Ontario Museum and analysed for mercury. It is unfortunate that these species are not the fish that exhibit elevated mercury levels. However, a long-term comparison of mean, minimum and maximum mercury levels does show that the mercury content has not substantially changed and trends cannot be established. Whitefish and cisco, both with specimens dating back to 1928 are shown in Figures 4.2 and 4.3. Yellow perch, sampled since 1952, are shown in Figure 4.4.

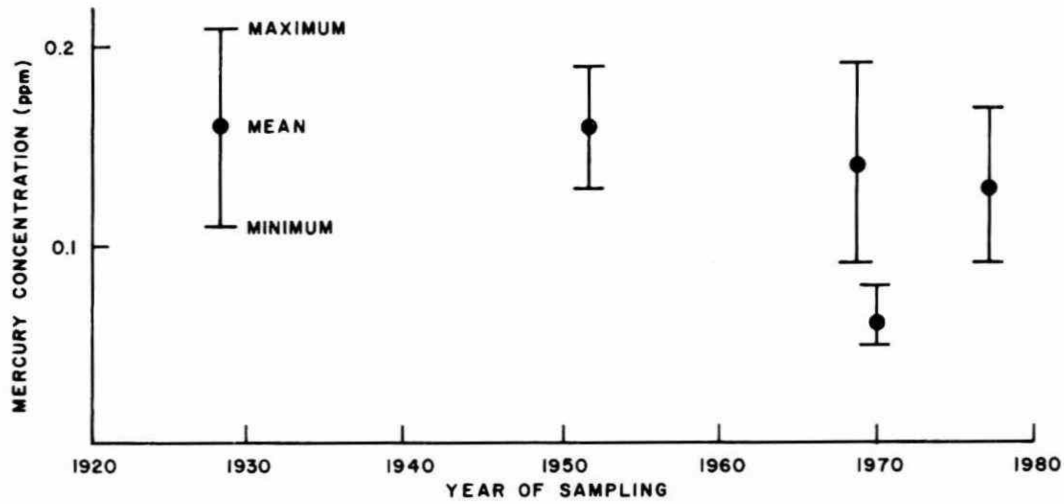


FIGURE 4.2 CISCO FROM LAKE SIMCOE

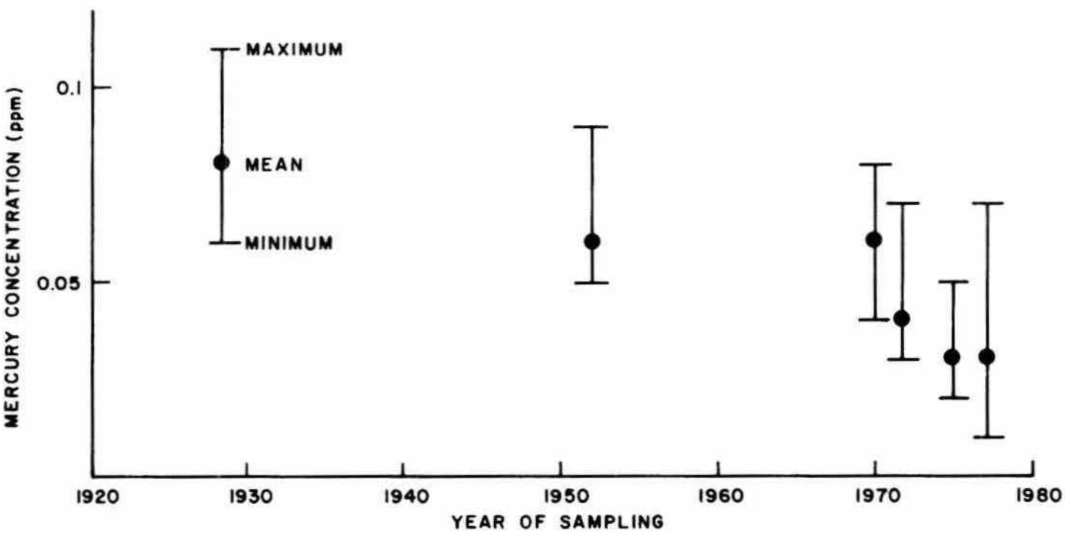


FIGURE 4.3 WHITEFISH FROM LAKE SIMCOE

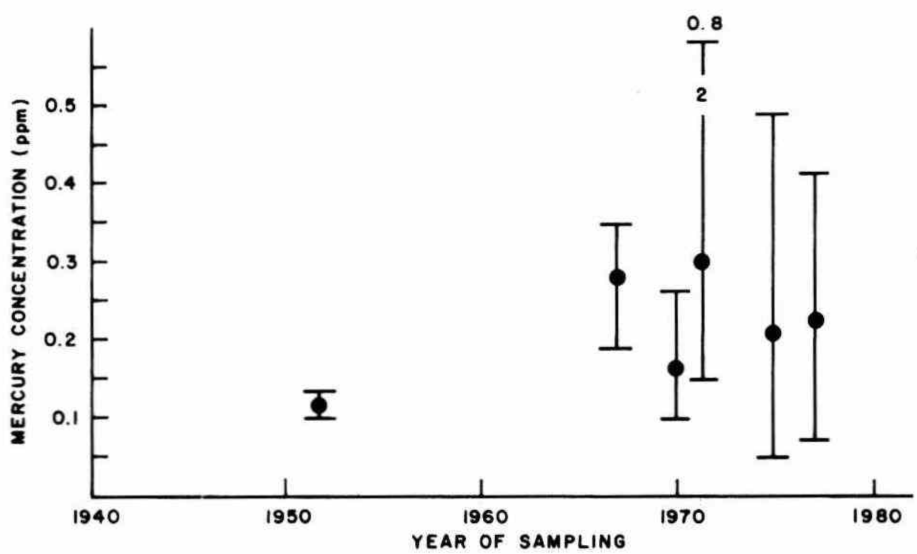


FIGURE 4.4 YELLOW PERCH FROM LAKE SIMCOE

5. DISCUSSION

The information collected during this study indicates no serious mercury pollution has occurred in Lake Simcoe. The lake water contains no measurable amounts of mercury. The lake sediments are generally low in mercury but around the larger municipalities some enrichment was found at concentrations that could be expected for urban areas without large industrial mercury users.

Some of the mercury found in certain industrial, commercial and household products does end up in municipal sewage. Although much of the mercury is removed during the sewage treatment process and retained in the digested sludge, some is discharged with the treated effluent. Also, municipal sewage by-passing a sewage treatment plant would contribute mercury to the aquatic environment.

The data show natural geologic sources of mercury to be very low and contributions from intensive agriculture in the Holland Marsh appear insignificant. Other sources that could be contributing small amounts of mercury to Lake Simcoe include runoff from sanitary landfill sites and sewage sludge disposal areas, urban stormwater runoff, golf courses that use mercurial fungicides and atmospheric sources. A major study to evaluate the significance and impact of atmospheric sources of mercury in Ontario is currently underway. Available resources did not permit a full-scale evaluation of the other possible sources mentioned but their impacts are likely quite small.

The species by species evaluation of fish collected from Lake Simcoe indicates that most fish of most species are low in mercury and quite safe to eat. Larger and older specimens of largemouth and smallmouth bass, walleye, lake trout and ling do contain mercury in excess of 0.5 parts per million and are thus subject to recommended consumption limits as laid out in the Ministry of the Environment's "Guide to Eating Ontario Sport Fish". The higher mercury levels in these fish is the result of the long-term ingestion of small amounts of mercury in the fish and organisms they feed on. With time, the mercury they have taken in bioaccumulate to elevated levels.

CONCLUSIONS

A review of all data collected through the Lake Simcoe mercury study indicates that the lake basin is not seriously contaminated by mercury. Low levels of pollution associated with mans' activities is resulting in some enrichment in sediments particularly in the vicinity of urban areas. Long-term bioaccumulation has resulted in elevated mercury levels in some older, predatory fish but for the most-part, the mercury concentration in most fish is low.

Based on the sediment analyses and source evaluation, there is evidence to suggest that low levels of mercury are continuing to enter the lake. Given this condition, it is likely that mercury concentrations in some large, predatory fish will continue to exceed levels suitable for unrestricted consumption for the foreseeable future.

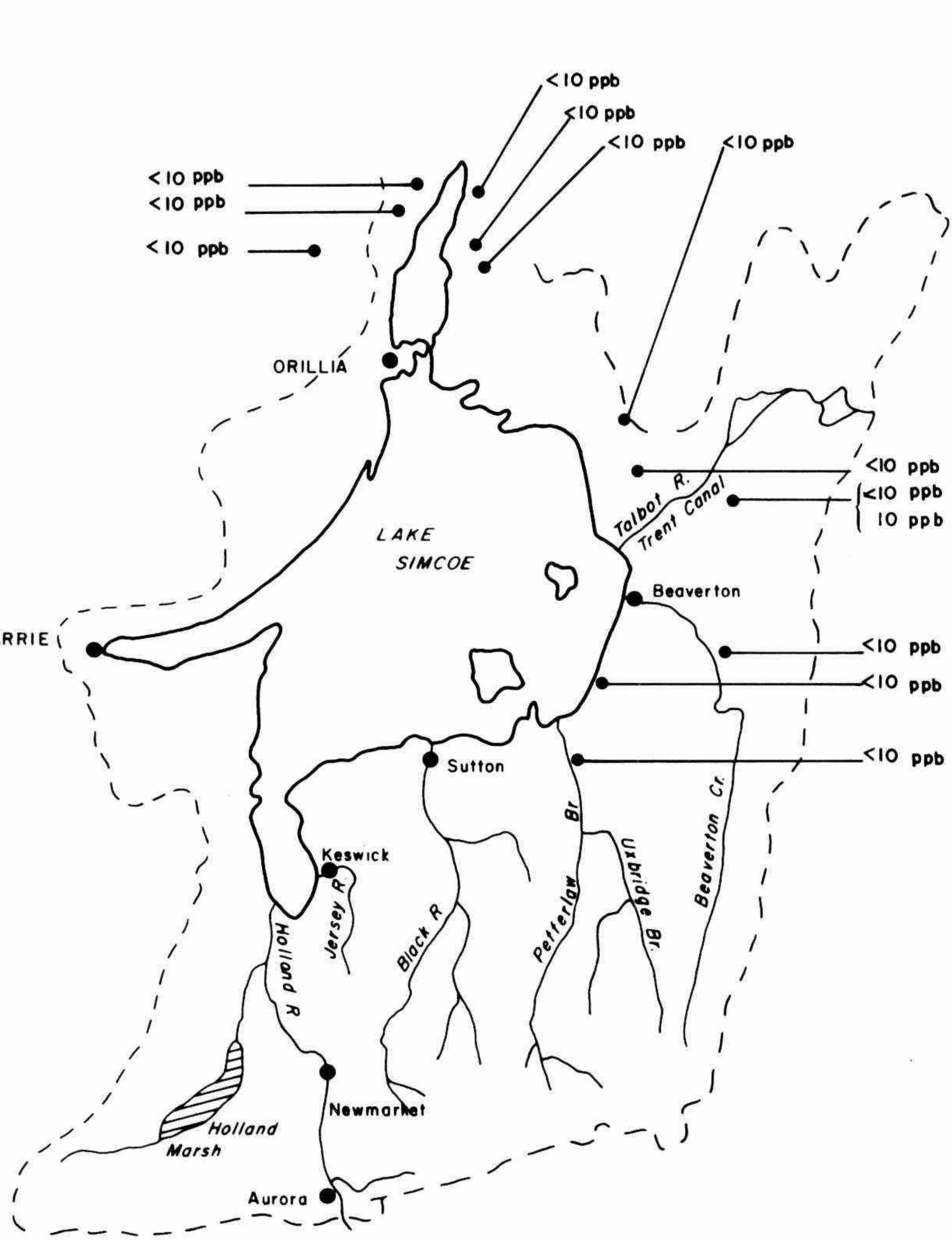
The removal of mercury enriched lakebed sediments in the vicinity of urban areas is not practically feasible nor, based on the data collected for this report, warranted. Positive measures such as ensuring that municipal sewage is not by-passed directly to the lake or tributaries and site selection and management practices to control runoff from sanitary landfill sites, sludge disposal areas, etc. should reduce future accumulations within the Lake Simcoe Basin.

APPENDICES

1. Mercury Concentrations in Bedrock

2. Detailed Information on Sediment Cores

3. Detailed Information on Mercury in Fish



NOTE: ALL STATIONS WERE SAMPLED IN DUPLICATE. WITH THE EXCEPTION OF THE STATION LOCATED JUST SOUTH OF THE TRENT CANAL, RESULTS OF ANALYSIS WERE CONSISTENTLY LESS THAN 10 ppb.

APPENDIX I: MERCURY CONCENTRATIONS IN BEDROCK IN THE LAKE SIMCOE BASIN. (GEOLOGICAL BRANCH - MINISTRY OF NATURAL RESOURCES)

APPENDIX 2

Detailed Information on Sediment Cores

A variety of sediment sampling methods were utilized to suit the various conditions of water depth and substrate type. Whenever possible, core samples were taken rather than grab samples to preserve the stratigraphy and permit accurate subsampling at different depths in the sediment.

During February and March, 1977, samples were taken through the ice with a push-rod corer (designed by Water Resources Branch staff) in water depths to 5 meters and with a Phleger gravity corer in deeper water. Triplicate cores were taken at 26 stations located throughout the lake. Mercury and other metals analyses were performed on the top segments (upper 4-10 centimeters) of two of the cores from each station. Values for the two samples were in such close agreement that further analyses with depth were performed on just one core to save analytical costs. The third set of cores from the winter, 1977 sampling survey were frozen and stored. Subsequently, selected cores from this set (Stations 21, 25 and 26) were subsampled at much smaller intervals and analysed for mercury. The analytical results and field notes for all the February-March, 1977 sediment samples are presented for stations 1 through 26 in the following tables.

In June, 1977, seventeen additional sediment cores were collected from the lake and Holland River Basin using the methods described above. Scuba divers were used to collect cores from Shingle Bay near Orillia. These 17 cores were also subsampled and analysed for mercury. Analytical results and field notes for the June, 1977 lake stations are identified A through G in the following Tables. Holland River Basin samples are identified H-1 through H-9.

APPENDIX 2 - DETAILED INFORMATION ON SEDIMENT CORES

STN. NO.	STN. DEPTH m	SAMPLE DATE	SAMPLE NO.	DEPTH INTERVAL cm.	% LOI	ug/g Hg	Pb	Zn	As	Cu	Cr	Description of Sample
1	1.5	25/2/77	60000	0-6	21	0.06	24	65	4.3	27	12	Push-rod core, organic, silty-fine sand (visible plant fibre. Cattail pieces, etc.), increasingly organic with depth.
			60001	10-16		<.01						
			60002	25-31		<.01						
			60003	0-7	19	0.06	35	57	4.8	28	14	" 41 cm duplicate core
2	1.5	10/3/77	60169	0-7	46	0.10	32	93	7.2	24	52	Push-rod core-soft, dark-grey silt with organic fibre and some shells. Firmer but still dark to black at depth.
			60170	17-24		0.64						
			60171	32-39		0.77						
			60172	0-6	45	0.09	33	94	7.0	24	53	As above but coarser organics, 40 cm duplicate core.
2	1.5	19/10/77	60307	0-8	47	0.04						As above
			60308	56-62	64	<.01						
3	1.0	10/3/77	60161A	0-7	51	0.12	42	140	5.3	23	160	Push-rod core highly organic silt (observed a red segmented worm) firm, brown inside - turned dark on exposure to air. A few shells in upper 10 cm.
			60162	21-28		0.56						
			60163	33-39		0.88						
			60164	0-6	48	0.13	43	140	5.0	24	160	38 cm duplicate core some organic detritus. Little decomposition.
		19/10/77	60309	0-6	40	0.06						
			60310	58-64	31	0.15						

STN. NO.	STN. DEPTH m	SAMPLE DATE	SAMPLE NO.	DEPTH INTERVAL cm.	% LOI	Hg (ug/g)	Pb (ug/g)	Zn (ug/g)	As (ug/g)	Cu (ug/g)	Cr (ug/g)	Description of Sample
4	1.0	10/3/77	60154	0-10	44	0.05	47	62.0	3.0	17.0	45.0	40 cm push-rod core. Highly organic brown silt with some shells (clam).
			60157	0-6	39	0.08	23	77.0	3.4	19.0	68.0	38 cm push-rod. Very soft, organic silt with some shells becoming almost peat at depth.
			60311	0-6	33	0.04						65 cm push-rod. (Same as above).
			60312	58-65	30	0.04						
5	3.5	10/3/77	60146	0-6		<.01						40 cm push-rod, soft, light-grey silt with organic detritus, becomes firmer with depth.
			60147	18-24		<.01						
			60148	34-40		0.03						
			60149	0-7		0.02						40 cm push-rod (as above).
6	1.7	25/2/77	60008	0-8	31	0.09	93	260	2.6	78	19	38 cm push-rod core - organic silt (organics very fine at top becoming coarser and more abundant with depth).
			60011	0-7	27	0.11	72	200	2.3	55	14	40 cm push-rod core. Very organic, sandy silt - no sand below 7 cm.
			60012	15-22		<.01						
			60013	33-39		<.01						
7	13.0	10/3/77	60138	0-10	16	0.09	42	85	3.3	19	64	37 cm Phleger core - Dark grey flocculent silt becoming firmer and lighter with depth.
			60139	19-27		0.01						
			60140	30-37		0.01						
			60141	0-9	16	0.07	40	82	3.7	19	67	34 cm Phleger core - Brown, flocculent material over grey silt. Few shells in lower 1/3 becomes firmer and lighter with depth.

Appendix 2 (cont.)

STN. NO.	STN. DEPTH m	SAMPLE DATE	SAMPLE NO.	DEPTH INTERVAL cm.	% LOI	Hg (ug/g)	Pb (ug/g)	Zn (ug/g)	As (ug/g)	Cu (ug/g)	Cr (ug/g)	Description of Sample
8	24	10/3/77	60130	0-9	17	0.07	60	100	4	21	45	35 cm Phleger core - dark-grey, flocculent silt. Firmer and lighter with depth.
			60133	0-9	18	0.07	83	100	3.09	21	44	33 cm Phleger core - same as above.
9	3.5	25/2/77	60016	0-6	8.4	0.01	-	32	0.84	4	7	37 cm push-rod core - firm, brown, organic, sandy-silt with shells.
			60019	0-6	12	0.02	-	50	1.3	-	7	31 cm push-rod core - brown, organic, sandy, silt with shells.
10	80	2/3/77	60038	0-9	10	0.03	15	57	3.3	13	22	34 cm Phleger core - soft, grey-black silt - gelatinous on top.
			60041	0-10	10	0.04	21	70	2.4	15	24	38 cm Phleger core-very soft, grey silt - very gelatinous.
			60042	14-24		0.02						
			60043	28-38		0.01						
11	80	2/3/77	60046	0-7	10	0.04	22	68	2.2	15	26	43 cm Phleger core - very soft, grey silt over sandy silt with shells.
			60049	0-7	16	0.05	31	79	2.3	15	27	39 cm Phleger core. Very soft silt 0-7 cm.; gelatinous silt 16-24 cm.; sandy silt with shells 31-39 cm.
				16-24		0.02						
				31-39		0.02						

STN. NO.	STN. DEPTH m	SAMPLE DATE	SAMPLE NO.	DEPTH INTERVAL cm.	% LOI	Hg	Pb	Zn	As	Cu	Cr	Description of Sample
						ug/g						
12	3.0	25/2/77	60024	0-7	10	0.03	14	52	1.2	10	15	39 cm push-rod core - organic, sandy silt over organic silty sand over sand and shells.
			60027	0-8	8.9	0.02	5.2	33	0.96	5.2	10	36 cm push-rod core. Some organics in silty sand with shells over sand and shells.
14	2.0	25/2/77	60034	0-6	3.3	0.02	-	210	1.2	-	44	24 cm push-rod core. 10 cm brown, sorted sand over black fine sand.
			60036	0-6	2.9	0.02	9.2	32	0.55	8	8	23 cm push-rod core. 9 cm silty sand (some worms). 8 cm clean sand. 6 cm silty sand.
			60037	17-23		0.02						
15	75.0	2/3/77	60053	0-8	14	0.06	29	77	2.8	15	25	38 cm Phleger core. Very soft, light-grey and dark-grey silt-gelatinous, lighter with depth.
			60054	8-18		0.04						
			60055	28-36		0.02						
			60056	0-8	14	0.04	22	80	2.8	15	22	34 cm Phleger core - same as above.
16	65.0	2/3/77	60061	0-9	9.3	0.03	14	62	1.7	13	22	44 cm Phleger core. Soft, grey silt followed by gelatinous material, firmer with some shells at depth.
			60064	0-10	9.2	0.04	17	66	1.7	14	24	44 cm Phleger core. Soft, grey silt becomes firm to gelatinous with depth.
			60065	18-26		0.04						
			60066	34-44		0.02						

Appendix 2 (cont.)

STN. NO.	STN. DEPTH m	SAMPLE DATE	SAMPLE NO.	DEPTH INTERVAL cm.	% LOI	Hg (ug/g)	Pb (ug/g)	Zn (ug/g)	As (ug/g)	Cu (ug/g)	Cr (ug/g)	Description of Sample
17	6.0	8/3/77	60069	0-8	2.4	0.01	3.6	17	0.8	3.6	11	19 cm Phleger core - silty-fine sand progressively firmer and greyer with depth.
			60071	0-8	3.3	0.01	4.1	14	0.75	3.8	7.1	20 cm Phleger core - brown, silty-fine sand with worms grading to firm, grey silt.
18	1.0	8/3/77	60074	0-8	19	0.05	24	73	1.5	16	22	40 cm push-rod core. Very soft, grey sandy-silt with organics. Darker and firmer with depth.
			60075	16-24		0.01						
			60076	32-40		0.03						
			60077	0-9	16	0.05	23	75	1.5	16	23	41 cm push-rod core. Same as above (ice to about one foot above bottom).
19	2.5	8/3/77	60082	0-8	5.3	0.01	12	36	0.93	13	25	34 cm push rod core. 2 cm loose sand over light-grey sandy-silt becomes harder with depth.
			60085	0-10	7.3	0.01	5.6	45	1.1	15	29	23 cm push-rod core. 2 cm loose silty sand with worms over light-grey, soft sandy-silt.
21	1.0	8/3/77	60098	0-8	20	0.58	94	220	2.5	65	88	39 cm push-rod core. Black, odorous, silty-sand with organic debris.
			60099	14-22		0.01						
			60100	30-39		0.01						
			60101	0-8	30	0-84	110	270	3.5	83	120	36 cm push-rod core. As above but coarser on top.
			60102	10-18		0.05						
			60103	26-36		0.02						
			60177	0-1		0.68						Black, odorous silty-sand with organic debris.
			60178	1-2		0.25						
			60179	2-3		0.83						
			60180	3-4		0.56						
			60181	10-11		0.92						
			60182	31-33		1.50						

STN. NO.	STN. DEPTH m	SAMPLE DATE	SAMPLE NO.	DEPTH INTERVAL cm.	% LOI	ug/g Hg	Pb	Zn	As	Cu	Cr	Description of Sample
22					STATION WAS TOO STONY TO OBTAIN ANY SAMPLE							
23	3.0	8/3/77	60090	0-8	4.8	0.03	3.1	17	0.96	8.9	10	42 cm push-rod core. Grey, sandy-silt with shells becoming light brown and firmer with depth.
			60093	0-10	8.7	0.01	3.1	18	0.46	9.2	15	41 cm push-rod core. Same as above.
24	40.0	10/3/77	60122	0-10	17	0.11	64	120	5.6	26	93	30 cm Phleger core. Dark-grey, flocculent, silt becoming firmer and lighter with depth.
			60123	10-20		<.01						
			60124	20-30		<.01						
			60125	0-8	18	0.12	79	140	5.8	27	130	29 cm Phleger core. Same as above.
			60183	0-1		0.11						20 cm Phleger core. Same as above.
			60184	1-2		0.10						
			60185	2-3		0.06						
25	30.0	10/3/77	60114	0-10	15	0.38	74	130	4.9	38	420	40 cm Phleger core. Flocculent, dark-grey silt becoming firmer and lighter with depth.
			60115	17-27								
			60116	31-40								
			60117	0-9	17	0.36	48	110	4.4	28	240	35 cm core. Same as above.
			60186	0-1		0.48						32 cm core. Same as above
			60187	1-2		0.60						
			60188	2-3		0.54						
			60189	3-4		0.46						
			60190	4-5		0.22						

Appendix 2 (cont.)

STN. NO.	STN. DEPTH m	SAMPLE DATE	SAMPLE NO.	DEPTH INTERVAL cm.	% LOI	ug/g Hg	Pb	Zn	As	Cu	Cr	Description of Sample
26	10	10/3/77	60106	0-20	13	0.66	110	200	3.3	74	1200	37 cm Phleger core. Very soft, black silt. Flocculent surface becomes light-grey with shells at depth.
			60107	20-30		0.08						
			60109	0-10	11	0.49	97	200	2.5	86	1200	30 cm Phleger core. Same as above.
			60110	10-20		0.10						
			60111	20-30		0.04						
			60191	0-1		0.98						26 cm Phleger core.
			60192	1-2		0.58						
			60193	2-3		0.53						
			60194	3-4		0.51						
			60195	4-5		0.45						
			60196	5-6		0.60						
			60197	10-11		0.54						

Appendix 2 (cont.)

STN. NO.	STN. DEPTH (m)	SAMPLE DATE	SAMPLE NO.	DEPTH INTERNAL (cm)	Hg (ug/g)	DESCRIPTION OF SAMPLE
A	40	16/6/77	60240	0-5	0.19	38 cm Phleger core.
			60241	11-16	0.05	Very soft, grey silt
			60242	21-27	0.03	with black zones near
			60243	33-38	0.03	top becoming firmer and lighter at depth.
B	30	16/6/77	60244	0-5	0.09	38 cm Phleger core.
			60245	8-13	0.06	Very soft, dark-grey
			60246	21-27	0.03	silt becoming firmer
			60247	33-38	0.02	and lighter with depth.
C	20	16/6/77	60248	0-7	0.03	54 cm Phleger core.
			60249	7-13	0.01	Very soft, light-grey
			60250	20-25	< 0.01	silt with dark bands
			60251	30-34	< 0.01	becoming firmer with
			60252	39-44	0.01	no dark areas below
			60253	49-54	< 0.01	13 cm.
D	14	16/6/77	60254	0-9	0.05	42 cm Phleger core.
			60255	15-21	0.02	Soft, dark-grey clay
			60256	26-31	0.01	becoming firmer and
			60257	36-42	0.01	lighter with depth.
E	2.5	16/6/77	60258	Surface grab	0.31	Diver-collected scoop of sediment between two sand bars offshore of Orillia STP. Organic and Macodorous.
F	10	16/6/77	60259	0-3	0.02	39 cm diver, push-rod
			60260	15-20	< 0.01	core. Sand, fine and
			60261	32-38	< 0.01	green/grey at top with some shells. Becoming coarser and dark-grey at depth.
G	10	16/6/77	60262	0-6	0.07	38 cm diver, push-rod
			60263	14-19	< 0.01	core. Loose, grey
			60264	23-28	0.01	silt becoming firmer
			60265	33-38	0.01	with depth.

Appendix 2 (cont.)

STN. NO.	STN. DEPTH (m)	SAMPLE DATE	SAMPLE NO.	DEPTH INTERNAL (cm)	Hg (ug/g)	DESCRIPTION OF SAMPLE
H-1	2	1/6/77	60217	0-5	0.02	27 cm push rod core. 5 cm coarse, brown sand becoming finer and greyer to 17 cm depth then brown and highly organic. (Organics filled 1/2 tube vertically with sand-silt in 10-17 cm segment - very unusual).
			60218	5-10	0.01	
			60219	10-17	<0.01	
			60220	17-22	0.01	
H-2	-	1/6/77	60221	surface	<0.01	Soil sample from Holland Marsh muck farming area.
H-3	2	1/6/77	60222	0-5	0.01	38 cm push rod core. Soft silt, light-brown at surface grading to dark-grey.
			60223	5-10	<0.01	
			60224	22-27	0.01	
			60225	33-38	0.01	
H-4	2	1/6/77	60226	0-6	0.05	30 cm push-rod core. Brown silt some dark zones of decomposing organics. Large number of shells partially near bottom of core.
			60227	6-11	0.04	
			60228	15-20	<0.01	
			60229	25-30	<0.01	
H-5	2.5	1/6/77	60230	0-5	0.16	15 cm push-rod core. Soft, grey silt over firmer silt with some thin sandy bands.
			60231	8-15	0.23	
H-6	1	1/6/77	60232	0-1	0.38	20 cm push-rod core. Odorous, black clay-silt becoming firmer with depth and including some debris.
			60233	7-14	0.36	
			60234	14-20	0.27	
H-7	1	1/6/77	60235	0-6	0.01	22 cm push rod core. Grey silt with worms over firm, buff clay.
			60236	15-22	0.01	

Appendix 2 (cont.)

STN. NO.	STN. DEPTH (m)	SAMPLE DATE	SAMPLE NO.	DEPTH INTERNAL (cm)	Hg (ug/g)	DESCRIPTION OF SAMPLE
H-8	0.25	1/6/77	60237 60238	surface surface	0.01 0.06	Surface sediments scooped from streambed 60237 - sandy with shells and worms. 60238 - sand, silt, organic debris and worms.
H-9	0.1	1/6/77	60239	surface	0.01	Shallow stream area fed by culverts draining sub-division - sandy sediment.

APPENDIX 3

Detailed Information on Mercury

in Fish Collected from Lake Simcoe

APPENDIX 3

Detailed Information on Mercury in Fish Collected from Lake Simcoe

SPECIES	Year of Collection	Number of Fish	Hg Concentration (ppm) Mean	Min.	Max.	Length of Fish (cm) Mean	Min.	Max.
Walleye	1970	22	0.27	0.07	0.96	51.9	30.7	75.2
(Pickerel)	1971	12	0.55	0.18	2.04	53.5	30.0	71.6
	1975	15	0.73	0.15	1.28	60.7	48.0	74.0
	1976	50	0.98	0.18	1.70	66.2	36.6	80.1
	1977	27	0.60	0.10	1.60	53.8	29.0	75.0
Lake Trout	1970	20	0.39	0.16	0.58	72.5	54.1	82.8
	1975	16	0.24	0.13	0.39	62.3	55.0	71.0
	1976	12	0.35	0.18	0.56	69.9	57.2	85.3
	1977	20	0.48	0.20	0.93	66.6	49.5	87.0
Whitefish	1915*	6	2.4**	1.4**	4.9**	38.0	35.4	44.5
	1928*	6	0.08	0.06	0.11	39.9	36.8	42.3
	1952*	10	0.06	0.05	0.09	19.3	17.5	23.3
	1970	11	0.06	0.04	0.08	44.3	35.6	49.0
	1971	12	0.04	0.03	0.07	43.8	40.4	47.7
	1975	13	0.03	0.02	0.05	46.9	44.0	51.0
	1977	20	0.03	0.01	0.07	52.2	50.8	54.5
Largemouth Bass	1971	12	0.25	0.14	0.50	30.8	19.3	42.2
Smallmouth Bass	1970	24	0.48	0.17	1.44	32.1	22.6	41.4
	1971	12	0.27	0.13	0.82	31.1	19.3	48.3
	1975	10	0.13	0.09	0.18	29.1	19.0	34.5
	1977	30	0.25	0.06	0.93	29.3	19.4	43.5

*Specimens from Royal Ontario Museum **Mercury Contamination of Preserving Fluid Suspected

Appendix 3 (cont.)

SPECIES	Year of Collection	Number of Fish	Hg Concentration (ppm) Mean	Min.	Max.	Length of Fish (cm) Mean	Min.	Max.
Rock Bass	1952*	3	0.20	0.18	0.24	22.2	21.7	22.7
	1970	12	0.14	0.10	0.24	17.4	13.5	21.3
	1975	10	0.16	0.08	0.25	21.5	17.0	25.0
Yellow Perch	1952*	4	0.12	0.10	0.13	14.5	13.4	15.5
	1967*	4	0.29	0.19	0.36	17.5	15.8	21.1
	1970	15	0.17	0.10	0.27	25.6	20.1	32.5
	1971	12	0.30	0.15	0.80	25.8	20.6	31.8
	1975	12	0.21	0.06	0.49	23.8	14.0	30.0
	1977	22	0.23	0.07	0.42	24.7	12.0	31.0
Northern Pike	1967*	2	0.13	0.12	0.14	43.4	-	-
	1971	12	0.19	0.12	0.44	69.8	54.9	96.5
	1975	3	0.16	0.05	0.31	63.0	43.0	86.0
	1977	22	0.20	0.07	0.47	67.4	51.2	105.0
Ling (Burbot)	1970	10	0.39	0.14	0.55	69.8	33.0	81.3
	1975	5	0.53	0.45	0.65	76.8	70.0	86.0
	1977	15	0.44	0.15	0.98	59.4	43.7	79.0
White Sucker	1952	4	0.04	0.03	0.05	30.6	23.8	35.9
	1970	12	0.17	0.09	0.23	43.0	38.4	46.5
	1971	12	0.09	0.05	0.14	41.4	35.0	48.0
	1975	6	0.14	0.07	0.19	43.5	39.0	46.0

*Specimens from Royal Ontario Museum

Appendix 3 (cont.)

SPECIES	Year of Collection	Number of Fish	Hg Concentration (ppm) Mean	Min.	Max.	Length of Fish (cm) Mean	Min.	Max.
Cisco	1928*	8	0.16	0.11	0.21	25.3	20.7	29.2
	1952*	9	0.16	0.13	0.19	20.0	18.3	21.3
	1969*	15	0.14	0.09	0.19	26.0	23.0	29.1
	1970	9	0.06	0.05	0.08	23.2	22.5	24.5
	1977	26	0.13	0.09	0.17	32.8	26.8	40.3
Rainbow Smelt	1970	10	0.08	0.05	0.11	20.9	16.8	24.9
Emerald Shiner	1971	4	0.08	0.06	0.11	7.6	5.1	10.0